Editorial

Publish to be damned!

One of the things that the OU imparts to its students is the value of critical observation and creative thought. The geological courses from the OU likewise show how it is possible to understand past things better by looking at them in as many different ways as possible. Perhaps we might take this even further. For instance, what remains of man's stay on this planet will be left 250 million years from now?

We can expect a few bones to be preserved, perhaps. They will almost certainly be those of people who died or were buried at sea on the continental margins. Other bones will have been shattered during erosion or consumed at plate margins. There will be a noticeable lack of oil and coal deposits, not to mention other ores, of pre-Permian origin, though the exact date of their removal, and the cause of it, will have been lost due to the effects of plate movement well before then. It is probable that there will be a noticeable period of sea invasion in the period representing the next few centuries as the greenhouse effect comes into play, and it is also possible that the spreading desertification over the last few centuries will produce noticeable geological results (the Ultra-new Red Sandstone?).

Some unusual small scale effects might baffle future geologists. What will a fossilised rubbish dump look like after metamorphism? Why will certain clays in oddly defined, deep, often circular, 'pools' have such high contents of unusual, often lethal, chemicals? (Fossilised settling ponds!) Why is there a large channel cutting through Cretaceous chalk in the area of what appears to have been a chalk escarpment between the site of Old Oxford and the High Wycombe anticline? (Friends of the M40 to the rescue! What river was it?) Why did many of the animal species and most of the trees die out in this period? What caused the Mediterranean to become anaerobic during this period? Was its connection to the Atlantic closed by earth movements during this period?

Looked at in this light the two million years or so that man's ancestors have been around become puny, and homo sapien almost irrelevant, unless we do succeed in turning this planet into a complete write-off, as we seem to be trying to do at this moment. But such reflections may cause us to look again at such things as past changes in sea-floor level, the sudden extinction of species (dinosaurs?), periods of desertification, etc, in a different light. Or to consider whether our understanding of the geological record is correct. One article in this issue challenges current thinking. Perhaps there should be more such critical thought coming from OUGS members.

Hopefully the trickle of articles will by now have turned into a stream, if not a flood. The next issue will mostly be devoted to the Conference proceedings, but we still need more field trips, project examples and normal scientific papers.

Martin Bryan

OUGS Insurance Policy

The OUGS has taken out a policy specifically designed to insure the society against any claims made against it or its members for damages or injury received as a result of the actions of society members or goods supplied by the society. The policy covers all the world outside the American continent and Warsaw Pact countries, and is limited to the sum of £250 000.

The policy does *not* cover:

liability to repair or replace any goods supplied by the society that are damaged whilst the injury and damage is being caused

cars or other vehicles that need a Certificate of Insurance.

The policy does, however, cover:

members property or property under the custody of a member damaged by another member or by goods and equipment supplied by or being used by the society, providing said property is not insured by any other policy. This does extend to cars and other vehicles

for damage caused by lifts, cranes, steam boilers, etc, used by the society in the course of any field work

claims arising due to any food poisoning resulting from food supplied by the society at any of its meetings.

Anybody wishing to make a claim on the society's policy should first contact the society's Secretary in writing. The claim request will be dealt with at the next Executive meeting, which may entail a slight delay. An acknowledgement of receipt of the claim will, however, be sent as soon as is possible, but it will not constitute acceptance of the claim. This remains the perogative of the Executive committee as it affects our no claims bonus!

OUGS Devil's Dictionary

Incompetent Layer a) One still in need of practice
b) Tutor in post-Summer School depression

Competent Layer Mythical beast, identified in fossil remains in above depression. Waltonian Hall series, assumed male of species. Later found to be hoax

Syncline Inclination discovered at Summer School and/or Conference

Unconformity Possible evidence of upheaval as a result of Syncline

Surely there is more than one anonymous OUGS devil!

The Meldon Reservoir

B J Cumbers

In the late 1950s, when a reservoir in north-west Dartmoor was first proposed, the water supply of the area was controlled by the North Devon Water Board. The area of supply, extending over 4310 km^2 (1664 sq. miles), was approximately the county of Devon north of a line from Tavistock to the Blackdown Hills.

Much of this area is underlain by Devonian and Carboniferous slates of very low porosity and permiability, yielding little water to wells. Most of the water supply is therefore drawn from surface run-off and from impounding reservoirs.

The rainfall is moderate to high, being highest on Dartmoor. The population is of low density (96 100 were supplied by the North Devon Water Board in 1960) but there is a high tourist influx during the driest months.

The need for a new reservoir

In the 1950s the demand in the area was being met by several small sources with two main works: Wistlandpound Reservoir on Exmoor in the north, and river extraction on the West Okement in the south. However, with the increasing per capita demand for water, together with the increasing influx of tourists in summer, the situation in the south of the area became critical. The drought of 1959 brought a severe shortage of water, only alleviated by an emergency supply from Taw Marsh.

By 1961 the drift deposits in the Taw Marsh area were being fully exploited for water. Nine shallow wells less than 60 feet deep draw water from the coarse river terrace sands and gravels at a rate of 1.25 m.g.d., with a resulting drawdown of only a few feet. This, however, would only supply water needs at the then current rate of increase in consumption until 1965. The increase in average per capita consumption was of the order of 1% per annum. Estimates made, dividing the area into north and south zones, showed that the immediate need in the 1960s was for more water in the south. The Board's consulting engineers were accordingly instructed to investigate likely sources.

Figure 1 shows the basic solid geology of the area. Very little underground storage exists in the south of the Water Board's area. The Carboniferous rocks which underlie most of it have a very low porosity (about 3%) and are largely impermeable. Water is commonly struck at the base of well-fissured beds where they overlie a shale or clay band, but the fissures are not well interconnected. Yield is therefore small, though storage may be considerable. The engineers regarded drilling in the Carboniferous rock as impractical for the yield required. The Dartmoor granite held even less possibility. The Permian sandstone and conglomerates in the area were already being exploited to the full as an aquifer.

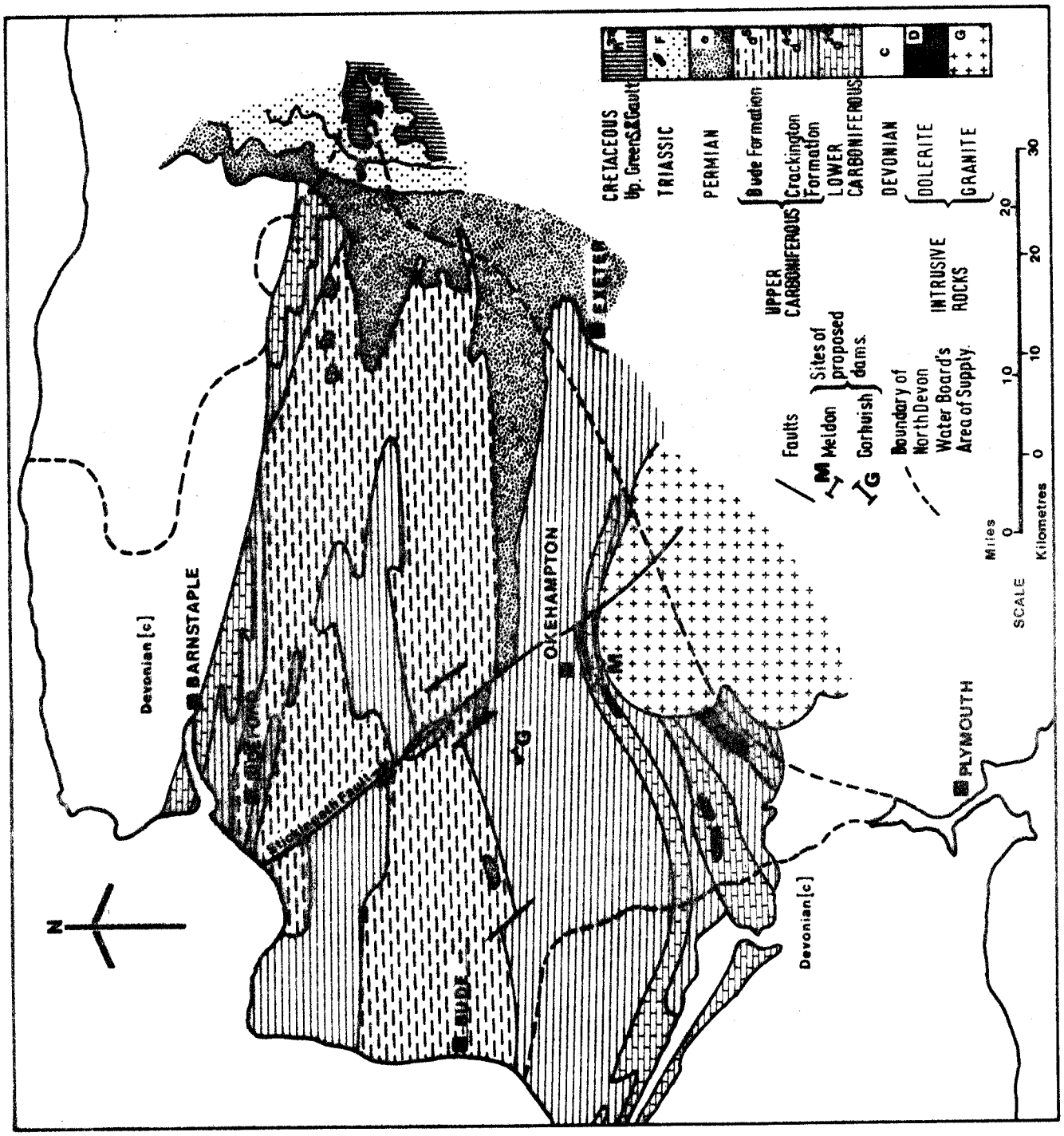
CRETACEOUS
Up. Green S & Gault
TRIASSIC
PERMIAN
Bude Formation
Crackington Formation
UPPER CARBONIFEROUS
LOWER CARBONIFEROUS
DEVONIAN
DOLERITE
GRANITE
INTRUSIVE ROCKS
Faults
Sites of proposed dams.
Meldon
Gorhuish
Boundary of North Devon Water Board's Area of Supply.
SCALE
Miles
Kilometres
BARNSTAPLE
OKEHAMPTON
EXETER
PLYMOUTH
BUDE
Devonian [c]
Devonian [c]
N

Figure 1

Medium and coarse grained drift deposits are not extensive in the area. The only considerable aquifer, Taw Marsh, was already supplying water. River gravels of the Taw and Torridge seemed a possible source, but were rejected for a number of reasons[1]: they are dirty, containing much silt and clay necessitating expensive treatmect of the water; the extraction would have to be at a low topographic level and would therefore need pumping to the demand area; and storage and recovery are severely limited by the fine particles in the gravel.

The engineer's report to the Board of April 1962, therefore, recommended the construction of an impounding reservoir.

The Selection of the Reservoir Site

There are five important considerations for the selection of dam sites: an adequate supply of high quality water; a reasonably watertight reservoir area; a geological structure strong enough to support the dam; elevation to provide water to the distributary system by gravity feed; and minimum detrimental effects on the ecology.

These factors, apart from the effect on the ecology, point to a valley on Dartmoor as the best site: Dartmoor has the highest rainfall and the greatest elevation in the area; the granite and the metamorphosed Carboniferous strata surrounding it are the most competent rocks; and they have the lowest porosity (1-4%) and permeabiliy of any rocks in the area. They also have fewer superficial deposits.

Water mains already existed from the Vellake intake on the West Okement River to treatment works at Prewley, and from there to the demand areas. This fact, plus the considerations above, led to the recommendation in the engineer's report for trial boreholes to be sunk in the upper part of the West Okement valley at Stengator, about 1300 feet above ordnance datum (a.o.d.). A site at Meldon was an alternative proposal, less favoured in the report as it was 400 feet lower.

Eleven reservoir sites were evaluated hydrologically before the final selection of Stengator or Meldon, but records of these were unfortunately lost during the reorganisation of the water authorities.

The War Department objected very strongly to the Stengator site, which was in an artillery range. The Dartmoor National Park Planning Committee also objected to Stengator as it is well within the Park, but they did not object to Meldon. Planning permission was therefore sought in June 1962 for boreholes at Meldon. It was not granted and the Water Board appealed to the Minister of Housing and Local Government. This was the beginning of the prolonged delay caused by environmental objections to the scheme.

The first public enquiry began on New Year's Day, 1963, at Okehampton. The inspector's viewing of the site was delayed by bad weather until March, but in May the Board's appeal was upheld and planning permission was granted.

[1] The river gravel investigation was not, in fact, made until August 1962, after planning permission for borings at a proposed reservoir site had been denied. The results are included here to complete the summary of underground and drift water sources.

The Meldon Site

The catchment area at Meldon is 4100 acres in extent, rising to about 2000 feet a.o.d. It is almost entirely uncultivated open moorland not crossed by any public roads. The organic pollution of the water would therefore be very low. There are some areas of ground water storage which are responsible for the relatively high dry weather flow of the river. The average annual rainfall is 76 inches.

The reservoir was planned to be formed by a concrete gravity dam about 660 feet long and 140 feet high. The top water level would be 903 feet a.o.d. and the proposed capacity was 680 million gallons. Compensation water below the dam would average 1.7 m.g.d.. The net reliable yield (calculated on the known drought flows of 1959) would be 5 m.g.d..

The water surface area was planned to be 54 acres so that, to allow a margin of 30 feet around the water's edge, the total land area needed was 74 acres.

Figure 2 is a geological map of the site and the surrounding area. The site is on folded Lower Carboniferous (Culm) rocks within the metamorphic aureole of the Dartmoor granite. Near Okehampton the Lower Carboniferous forms a long inlier in the Upper Carboniferous Crackington Formation, roughly parallel to the granite outcrop. The strata have been baked to varying degrees by the intrusion of the granite and are thus hard with a tendency to cleavage in the finer-grained types. They are appreciably harder and more competent than Carboniferous rocks elsewhere in the country.

The Carboniferous rocks are folded on a NE-SW axis and the folds are overturned. The reservoir site is on the overturned southern limb of an anticline. The strata are therefore inverted but show a northerly dip of between 45 and 65 degrees.

As expected in folding of this severity there are a number of strike faults, commonly parallel to the bedding. These are frequently found to be intruded by dykes of dolerite or of micro-granite.

The Prewley Fault is the only major fault in the reservoir area. The rocks at the southern end of the site are 300 yards dextrally displaced, the displacement decreasing north-eastwards.

A mineral lode in the chert passes along the reservoir. It contains chalcopyrite and arsenopyrite with pyrite, pyrrhotite and minor cassiterite. There were two mines which would be flooded by the reservoir, both with spoil tips containing arsenopyrite. The gangue minerals are quartz and calcite.

Eleven boreholes were sunk on or near the dam site, as shown in Figure 2. The soil and recent deposits are thin (less than 10 feet at their thickest) and would not be required to bear any load. The rocks are all hard and competent, as was shown by the solidity of the cores and the high percentage of core recovery. The ironstaining of the cores due to seepage along the joints and fissures is not

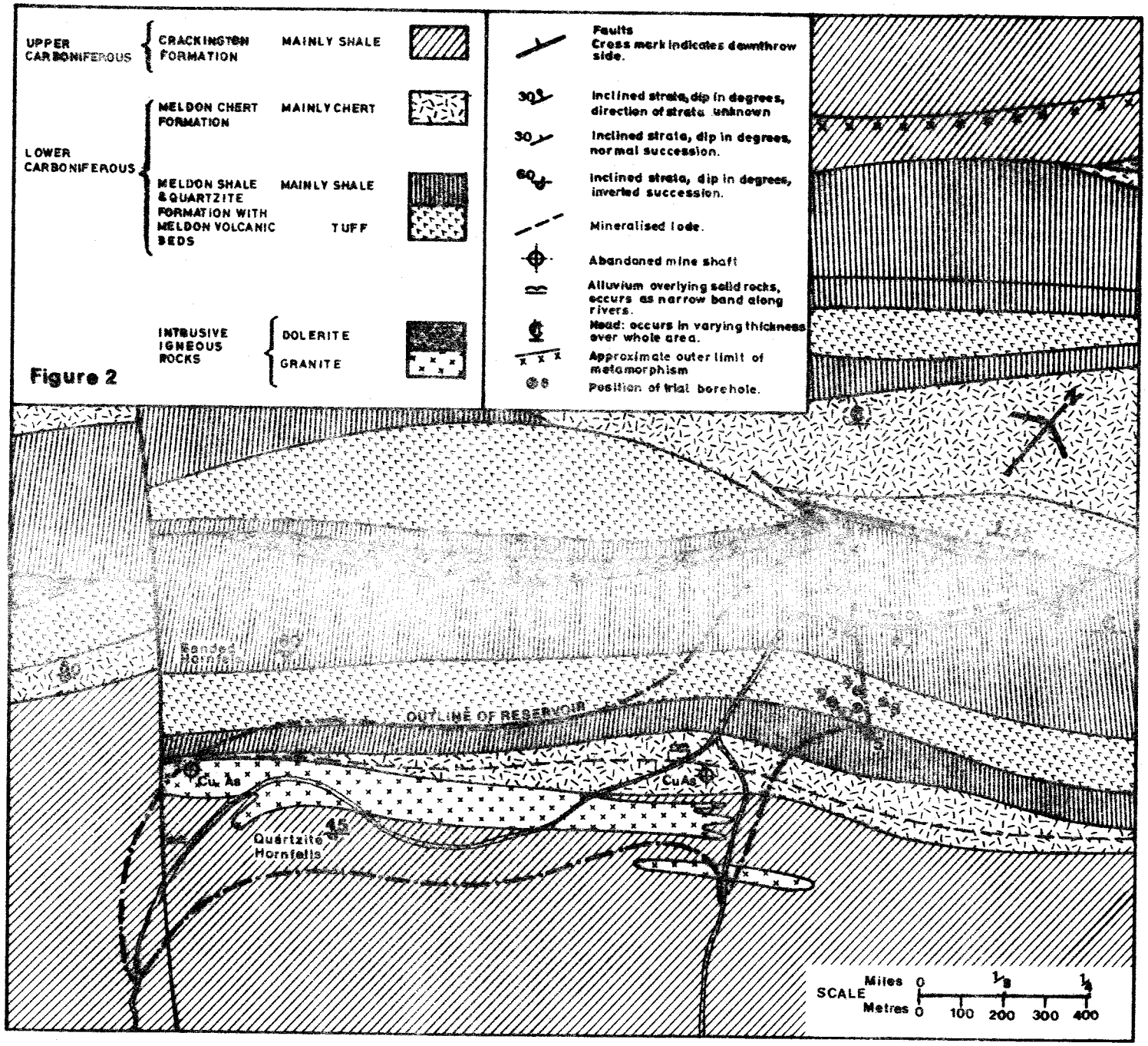
UPPER CARBONIFEROUS
CRACKINGTON FORMATION
MAINLY SHALE
LOWER CARBONIFEROUS
MELDON CHERT FORMATION
MAINLY CHERT
MELDON SHALE & QUARTZITE FORMATION WITH MELDON VOLCANIC BEDS
MAINLY SHALE
TUFF
INTRUSIVE IGNEOUS ROCKS
DOLERITE
GRANITE
Faults
Cross mark indicates downthrow side.
Inclined strata, dip in degrees, direction of strata unknown
Inclined strata, dip in degrees, normal succession.
Inclined strata, dip in degrees, inverted succession.
Mineralised lode.
Abandoned mine shaft
Alluvium overlying solid rocks, occurs as narrow band along rivers.
Head: occurs in varying thickness over whole area.
Approximate outer limit of metamorphism
Position of trial borehole.
Banded Hornfels
OUTLINE OF RESERVOIR
Cu As
Cu As
Quartzite Hornfels
SCALE
Miles 0 1/8 1/4
Metres 0 100 200 300 400

Figure 2

significant in a load-bearing context because it had not led to any appreciable decomposition or softening of the rock. The Water Board's consultant geologist, Edgar Morton, regarded the strata as satisfactory for the foundations and abutments of a concrete gravity dam, except that local deepening of the foundations might be necessary around borehole 4, where a thin dyke of micro-granite was found to have a decomposed core. Local deepening might also have been necessary on the north-west slope between boreholes 1 and 2 if the fracture zone encountered in borehole 6 was found to cross the site of the dam.

Boreholes 4, 8, 9 and 10 on the south-eastern hillside were found to lose water, though boreholes 6 and 11 on the same slope maintained standing levels. Mr Morton therefore recommended grouting of the strata beneath and beyond the heel trench and wing trenches to limit possible seepage losses through joints and fissures. (In the event, no problems were encountered in the foundations: there were no large fissures or zones of decomposed rock and there were exceptionally low takes of foundation grouting.)

Sealing was thought unnecessary away from the dam. The strata are jointed and fissured, but it was found from the boreholes that with increasing depth joints and fissures became narrower and eventually closed up. The ironstaining indicating seepage of groundwater in fact reduced at depth in some cores. The permeability of the strata underlying the reservoir site was, therefore, considered so low that lateral water loss would be insignificant.

The hard, baked nature of the strata makes slipping along the bedding planes unlikely, so the steep dip was not considered a hazard. A certain amount of impounded water would be lost along the fault planes on the site, but this was considered safe and acceptable.

There is no significant organic pollution of the water as the catchment area is very sparsely populated and is not used for farming. All nitrogen compound concentrations are extremely low in the West Okement. The water is slightly discoloured by peat and has a pH of 6.8-7.3.

The question of arsenic pollution was raised during a later investigation. Soils were collected from areas of mineralisation and shaken in water for 16 hours. The water was then subjected to normal treatment, which reduced the concentration of arsenic to below the detection limit (0.005mg/l). Other tests also proved satisfactory. Nevertheless, the Water Board arranged for the complete removal of the spoil tips before the construction of the reservoir.

The solids suspended in the river were found to be less than 5 parts per million. There should, therefore, be no significant silting up behind the dam.

A concrete gravity dam could be constructed relatively cheaply on the site because of the general soundness of the strata. Suitable coarse aggregate would be available from the Meldon Quarry with little transportation cost.

History of the Scheme 1964-1972

The engineer's report to the Board in April 1964 stated that both on engineering and financial grounds the construction of a concrete gravity dam at Meldon was viable. Application was therefore made in July 1964 for the approval of the North Devon (Meldon Reservoir) Water Order.

At the Public Enquiry into the application there were 21 objections, all but two on behalf of organisations or persons concerned with the amenities of the area: there were no objections from local landowners or by people living in the locality. The need for the reservoir was not questioned: the concern was solely with the site.

There was no specific objections to the Meldon Valley as the site of the reservoir: the ecology there is in no way unique. The environmentalists' case was against any reservoir within the National Park. Their arguments were chiefly that: a dam is ugly when viewed from below; a reservoir is ugly when drawn down; the approach would be curtailed by fences and prohibitions; and standing water is foreign to the character of Dartmoor. The engineers commented that there would, in fact, be no prohibitions on approach to the reservoir, the fences only being there for safety; the site's steep sides would lessen the area of mud and silt exposed when the water was low; and the overall view of the valley is somewhat marred by Meldon Quarry and Meldon Viaduct.

The objectors sought to persuade the Inspector that a suitable alternative site existed at Gorhuish on the Hookmoor Brook (the location of which is shown on Figure 1). It is a wooded agricultural valley with gently sloping sides, and the proposition of a reservoir there was strongly opposed by the National Farmers Union and the Okehampton Rural District Council.

The Inspector finally supported the Water Board, subject to the carrying out of modifications that would limit as far as possible the effect on the landscape. The Order was made on November 15th 1966, after a seventeen month delay.

Nine objectors appealed against the Order and it therefore became necessary to put it to Parliament. The Parliamentary procedures were long and complicated, but eventually, in July 1967, a Joint Committee of the House of Lords and House of Commons concluded that, although the Meldon scheme was a viable one, it should only be proceded with if investigations of the Gorhuish site proved it to be impractical or significantly more expensive than Meldon.

The Water Board arranged for an investigation of the Gorhuish site to be carried out, and a Technical Committee was set up to enquire into the merits and costs of both schemes.

The Gorhuish site is on the Upper Carboniferous Crackington Formation outside the metamorphic aureole of the Dartmoor granite. The rocks are mainly grey, splintery, shales and mudstones with thin sandstone bands. The sandstones are commonly hard, fine grained, brownish-grey turbidites, usually less than a foot thick. Most of the shales and mudstones are finely laminated with carbonaceous layers, and some of the mudstones are calcified. Thin quartz veins occur, and there is some ironstaining on beds and joints. The folding is tight and the general

dip is north-north-westerly. Some of the strata are overturned, a hinge fold is exposed at the tip of the proposed reservoir, the dips are steep on the whole, and the beds contain faults and thrusts with slickensides. The overlying soils are clayey, with shale and mudstone fragments increasingly prevalant with depth. The alluvium is a soft, silty, clay.

Ten cored boreholes were sunk on or near the proposed dam site, five of which were converted to observation holes for monitoring the groundwater level. As at Meldon there was a high percentage of core recovery in the solid rocks, showing their competence, but unlike Meldon the top 25 feet showed considerable signs of weathering. Minor faults, slickensides and disturbed strata were found in four of the cores, though Mr. Morton considered these unlikely to have any practical significance. The load-bearing ability of the strata was considered less sure than Meldon and broad foundations at least 40 feet deep were recommended to avoid the weathered rock.

The ironstaining indicating permeability decreased with depth, but the consistency of the water levels in each of the boreholes indicated that the fissures and joints interconnect, thus increasing the permeability of the rocks. The depth of the broad foundation necessitated by the weathered rock would, however, probably also make the permeable rocks safe. More grouting would be necessary than at Meldon, with holes at 20 foot intervals and down to about 100 feet below ground level. Relief wells would be needed because of the artesian conditions in one borehole.

There are not enough superficial deposits in the valley to form an earth dam, and the rock is unsuitable for a rock-fill dam. A concrete gravity dam was, therefore, recommended, utilising aggregate from Meldon Quarry. In view of its greater lateral extent and the deeper foundations necessary, the Gorhuish dam was considered likely to be considerably more expensive than the Meldon one.

The catchment area of the Hookmoor Brook at Gorhuish extends over 2760 acres, of which 96% is farmland. There is, therefore, more vegetation and more potential sources of pollution (including a sheep dip and a municipal refuse tip) than at Meldon. Nitrogen compound concentrations are 10 to 20 times higher at Gorhuish, though still not excessive, and treatment to remove them would not be unduly difficult or expensive. The Gorhuish valley floor is, however, marshy and this may cause a high concentration of manganese in the reservoir water in hot weather. This is difficult and costly to remove. Dr. Hoather of the Devonshire Public Health Laboratories considered in his report that the cost of treatment of water from Gorhuish could be 50% higher than from Meldon. He also recommended that the sheep dip and the refuse tip be removed from the catchment area.

Suspended solids amount to between 70 and 150 parts per million in the Hookmoor Brook and would cause more silting up of the reservoir than would occur at Meldon.

A statistical comparison of the two schemes is shown in Table 1, together with estimates of the costs. In spite of its greater capacity the Gorhuish scheme would

provide no more water than Meldon and would be more expensive both to build and to operate.

	Meldon	Gorhuish
Catchment area (acres)	4100	2760
Characteristics	Moorland, mostly granite	Farm and woodland. Alluvium overlying mudstones
Av. summer run-off (inches)	14.6	8.0
Av. winter run-off (inches)	43.9	24.0
Spillway level (feet a.o.d.)	903.00	500.00
Height of dam (feet)	138	113
Length of crest (feet)	660	950
Storage capacity (million gallons)	710	1300
Surface area (acres)	54	135
Land needed (acres)	74	225
Net yield (m.g.d.)	5.0	5.0
Peak abstraction rate (m.g.d.)	6.2	6.0
Cost estimates (1968):		
Annual operation	£32 445	£49 070
Total capital cost	£2 234 400	£3 244 430

Table 1 Statistical comparison of the Meldon and Gorhuish schemes, including 1968 cost estimates

The chairman of the Technical Committee presented his report to the Minister in July 1968. At that time the investigation into arsenic pollution at Meldon was still going on and a report on this was presented in October 1968. After considering both these reports the Minister decided that the North Devon (Meldon Reservoir) Water Order should be brought into operation on December 2nd 1968.

Planning consent was granted on December 9th 1968, followed by consent for the enclosure of common land in January 1969. After tests on the dam design, work started in March 1970 and impounding began on March 15th 1972.

The Reservoir in Use

The Dartmoor National Park Planning Committee has supervised the construction of a public car park and picnic area near the dam. A slipway has been constructed for dinghies, and sailing is encouraged. The upper end of the reservoir has been designated a nature reserve, with an artificial island as a bird sanctuary. This is the only part of the reservoir to which the public is denied access.

The reservoir was originally designed to serve the southern part of the North Devon Water Board's area of supply, but in 1974 the water authorities were

reorganised and north Devon became part of the South West Water Authority's area, which extends over the whole of the south west peninsula. Meldon was, therefore, able to help a wider area in the severe droughts of 1975 and 1976. Its situation in the centre of Devon enabled it to play a key role in the complicated balancing of water resources in the county.

Concluding Comments

The Meldon story clearly illustrates the conflict of land use involved in the exploitation of almost any physical resource. The environmentalists' arguments have necessarily been very briefly presented here,[2] but it should be stressed that they are unspecific: the Meldon valley was of no unique ecological interest. The loss of 74 acres from a National Park of over 200 000 acres should hardly prove catastrophic, particularly in a valley already marred by the sight and sound of a large working quarry.

[2] The arguments are discussed in Lady Sayer and Brian Le Messurier's interesting, though highly emotively worded, article in *New Scientist*, February 6th 1969.

Further Reading

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Dearman, W. R. (1959). The structure of the Culm Measures at Meldon, near Okehampton, north Devon. *Q. J. Geol. Soc. London*, 115, 65-106.

Edmonds, E. A. *et al* (1968). The geology of the country around Okehampton: explanation of the one-inch geological sheet 324, new series. *Inst. Geol. Sci.*, 1968.

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Acknowledgments

I would like to thank Mr. C. Burton of the South West Water Authority for his help in going through old records, and Messrs. Rofe, Kennard and Lapworth, Chartered Civil Engineers, for the loan of the relevant reports.

Energy Facts

Between 1958 and 1978 Britain increased its energy consumption by 34%. Coal consumption declined by 59% during this period, though it still supplies 35% of all British energy. Gas showed a staggering 65 000% increase, now supplying some 19% of our needs. Petroleum only rose by 290%, though it now supplies 41% of all our energy, whilst the use of nuclear energy rose by 13 400%, though only to 4% of total energy use. Hydro-electricity remained almost static, supplying just under 1% of demand.

GEOLOGY AND THE BIBLE

John W. Saunderson

Synopsis

This article, as the title suggests, deals with the relationship between the science of geology and the Bible. It considers the limitations of each as a method of finding the truth, considers major areas of debate, outlines the main variations of Biblical and evolutionary theories and makes suggestions as to which areas can profitably be investigated. An original hypothesis is put forward for consideration.

What have geology and the Bible in common? Perhaps more than you think! In any case I thought that it would be a suitable topic for an article in the OUGS Journal, and I give the following reasons for thinking so:

a) There must be some OU geology students who are Christians and would like a bit of help with the topic. Actually there are increasing numbers of students at other universities who are becoming Christians, and taking the statements of the Bible more literally than has been the case for many years.

b) The old argument of 'Special Creation' versus 'Evolution' is likely to be a major debating point again. Much new scientific data favours the 'Special Creation' side and the arguments will be advanced scientifically rather than theologically.

c) The OU geology course does not even mention that there is such a hypothesis as 'Special Creation'.

Scientific Method versus the Bible

Scientific Method

The scientific method is only suitable for investigating material phenomena such as 'matter' and 'forms of energy'. This makes it an ideal method for investigating 'geology' and 'astronomy'. It is, however, most unsuited to investigating topics such as 'God' or even 'the origin of matter'.

The Bible

The Bible is not really concerned with topics like 'geology', but rather is concerned with such matters as 'sin', 'right and wrong', 'salvation' and 'judgement'. However, the Bible does have something to say about 'origins' – including the origin of the material universe.

Many other religions have sacred writings which state how the universe came into being, but these are seldom regarded as worthy of scientific investigation. There are many Christians who maintain that the Bible statements are meant to

be accepted literally, and so will stand up to scientific investigation. There is, in fact, an historical correlation between 'the attitude of society to the Bible' and 'scientific progress'. It would therefore seem that not only are science and the Bible not in conflict, but a study of the Bible is a benefit to a study of science (*see* AMST283 for more detail).

What does the Bible say about 'Geology'?

Actually, the Bible has little to say, though what it does say, as is normal in the Bible, is very significant and very important to the whole message.

The geolgical content can be summarised as:

i) The Earth was created by God – 'In the beginning' (Genesis 1, verse 1).

ii) A state of chaos, involving water and wind (or God's spirit) (Genesis 1, verse 2).

iii) A systematic ordering of creation by a number of deliberate acts or statements by God:

   a) Light

   b) Separation to form sky, land and sea

   c) Plants and trees

   d) Sun, moon and stars

   e) Birds, fish and water creatures

   f) Animals, and man as a special act (Adam).

   This creation is stated as taking place in six days (Genesis 1, verses 3 to 25).

iv) The fall of man – man rebels against God's control. This results in the Earth being 'cursed', an event which may be of interest geologically (Genesis 3).

v) The Earth is destroyed by a flood, other geological events possibly taking place at the same time (Genesis 6 to 8).

vi) A well documented historical record starts about 2000BC with Abram, since which time there are no records of anything other than the occasional earthquake or volcanic eruption.

The events of interest to the geologist are confined to the first eight chapters of the Bible. The time interval involved being something between 2000 and 6500 years. A genealogy is given from Adam to Abraham, with dates, but time may have been recorded a little differently.

Evolution versus Special Creation

There is often some blurring of the distinction between 'Scientific hypothesis', 'Scientific theory' and 'Scientific fact'. Christians accept as 'fact' the statements of the Bible regarding the creation. Atheists accept the 'theory' of evolution with almost religious fervour. The topic is very seldom treated in a normal rational scientific manner, or even as a matter of normal biblical debate. It seems to be a most emotive subject, so let's look at the areas of major disagreement.

Biblical Problems

There are a number of different interpretations of the Bible statements. These statements are extemely 'bare'. They were originally written in Hebrew – not a very suitable language for conveying precise scientific statements – and some of the important words are not easily translated. Scholars argue about the meaning of words like 'create', 'chaos', 'spirit' and 'day'. For example, it would be very nice to know for sure if 'create' really means 'make from nothing', while 'make' means 'make from something already there'. Also does 'day' mean 24 hours? Figure 1 should help you to make sense of the main variations. There is agreement on the main issues, and the differences are rather minor to the main argument, but they are, nevertheless, confusing.

Geological problems

In the past there has been wide ranging debate on a number of geological theories. This discussion has been good for the science of geology. Examples are:

i) Neptunism versus Vulcanism – were rocks formed by water or by volcanic action?

ii) Catastrophism versus Uniformitarianism – were the rocks formed in the past by violent geological activity, or could events be explained by geologiclal events of the same magnitude as at present?

iii) Cooling Earth versus Plate Tectonics – were mountains formed by cooling or collision?

The OU geology courses deal with both sides of these arguments and come to a conclusion, but fails to deal as fairly with the Evolution versus Creation issue.

Section 3 of Block 3 of S23 does point out some of the predictions which should be fulfilled if the Theory of Evolution is to be tenable. It then goes on to state that 'The evidence is not really convincing.....'. It then deals with two cases of variation by natural selection within a species (which is not the point at issue), relates this to evolution from one species to another, goes on to accept the theory as a working hypothesis and makes use of it for the dating of geological strata. This approach is somewhat less than scientific, but, to be fair, is a more reasonable treatment than most textbooks I have read on the subject.

A truly scientific investigation?

The scientific method requires three steps:

i) collect the evidence and structure it

ii) deduce a consistent hypothesis or hypotheses

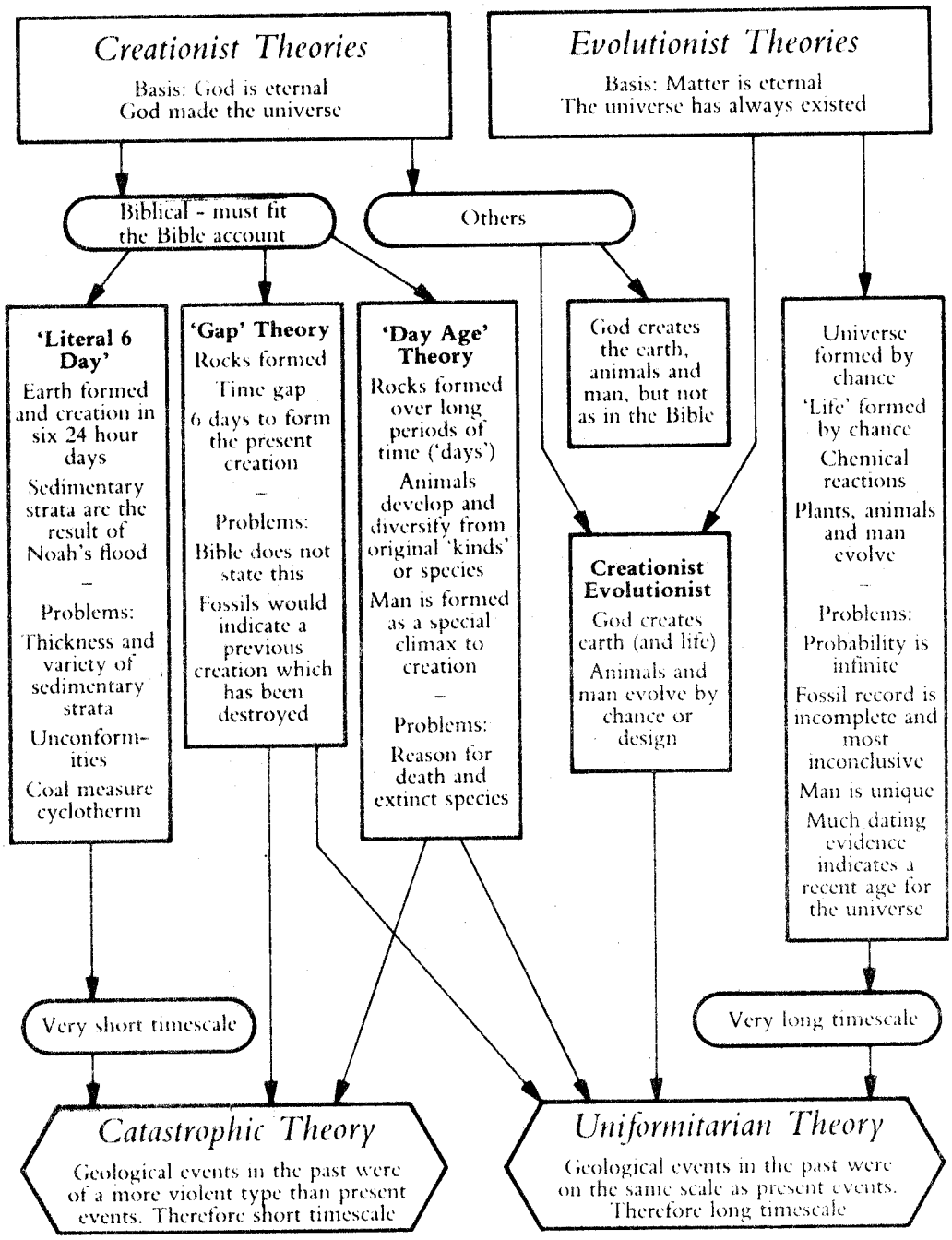
iii) test each hypothesis in the light of further evidence.

This approach seemed to work fairly well at Summer School.

So what is required is:

a) an evolutionary hypothesis (available in S23)

Basic Theories for the Formation of Rocks


Creationist Theories
Basis: God is eternal
God made the universe
Evolutionist Theories
Basis: Matter is eternal
The universe has always existed
Biblical - must fit the Bible account
Others
'Literal 6 Day'
Earth formed and creation in six 24 hour days
Sedimentary strata are the result of Noah's flood
–
Problems:
Thickness and variety of sedimentary strata
Unconformities
Coal measure cyclotherm
'Gap' Theory
Rocks formed
Time gap
6 days to form the present creation
–
Problems:
Bible does not state this
Fossils would indicate a previous creation which has been destroyed
'Day Age' Theory
Rocks formed over long periods of time ('days')
Animals develop and diversify from original 'kinds' or species
Man is formed as a special climax to creation
–
Problems:
Reason for death and extinct species
God creates the earth, animals and man, but not as in the Bible
Creationist Evolutionist
God creates earth (and life)
Animals and man evolve by chance or design
Universe formed by chance
'Life' formed by chance
Chemical reactions
Plants, animals and man evolve
–
Problems:
Probability is infinite
Fossil record is incomplete and most inconclusive
Man is unique
Much dating evidence indicates a recent age for the universe
Very short timescale
Very long timescale
Catastrophic Theory
Geological events in the past were of a more violent type than present events. Therefore short timescale
Uniformitarian Theory
Geological events in the past were on the same scale as present events. Therefore long timescale

Each of these views is held by people who are qualified to call themselves 'geologists'. The 'middle ground' between the extremes is extremely broad and probably includes most geologists

b) a creationary hypothesis (supplied later)

c) a devoted band of budding OU geologists to put them to the test.

An Evolutionary Theory

This requires an extremely long timescale. There is no evidence of evolution from one species to another in historic time. The incomplete fossil record conveniently omits to record a single important transitionary form. There is evidence of adaption of a species to its environment and its lifestyle, but this is not at issue. The time for adaption would indicate an enormous timescale for a minute evolutionary change. The dates shown next to Cambrian, Ordovician, etc, are based on evolutionary criteria, so are open to question. Dating methods such as carbon and argon dating depend on the theory that present events faithfully represent the situation in the past. For example, the amount of carbon dioxide in the atmosphere and the proportion of radioactive carbon in this are assumed to be constant for this purpose, but different for other purposes. So, if these methods are disallowed, we have to look for more fundamental evidence.

Having confused the issue, I want to go even further and add yet another Biblical Creationist Hypothesis for your consideration.

A Creationist Hypothesis

Phase 1 – A Perfect Earth: A perfect Earth is created by God for man to inhabit. It not only has hills, rivers and vegetation, but also minerals for man to mine and exploit. It has an inbuilt geological age. In other words, the limestones have shell fossils in it and there is already igneous activity. There is an inbuilt mechanism of sea floor spreading to ensure that mountains and minerals can be rejuvenated as required. (Pre-Carboniferous.)

Phase 2 – A Cursed Earth: The situation now is one in which man has to work hard; weeds and thorns are part of the problem. A time of great geological activity with faults and folding. There are very few men around (those who are live in geologically static regions) but they live to great ages. The climate was very different, there was no rain but the Earth was watered by a mist. There was probably a water-vapour canopy surrounding the Earth at this time. (Carboniferous to Cretaceous.)

Phase 3 – A Universal Flood: Rain falls for the first time, and the 'fountains of the deep' or 'waters under the Earth', probably combined with the collapse of the water-vapour canopy, cause a flood. Noah's ark is used to preserve human and animal life. Dinosaurs become extinct as they are too big to preserve. The Bible quotes the following times:

40 days flood conditions being established
150 days before the flood starts to go down
150 days in going down.

This makes about a year. Noah is able to step out on an Earth with trees and normal vegetation. (Most of the Cenozoic.)

Phase 4 – Modern Historic Times: A number of changes are mentioned in the Bible:

a) the rainbow is first seen

b) man becomes a meat eater

c) the earth is no longer to be 'cursed'.

Major geological change ceases, uniformitarian events are now the norm. Climatic changes lead to an ice age.

Conclusions

I maintain that there is a very good cause for the Creation as well as Evolutionary theories to be considered by OU geologists on the following grounds:

1 The starting point of 'God created the Earth' or 'matter has always existed' are equally 'scientific'.

2 While personally finding it a little difficult to accept the possibility that all sedimentary strata, including the Carboniferous series of coal seams, were all formed by Noah's flood, I find that the Biblical record gives adequate scope for a multitude of 'middle ground' theories. My own suggestion is actually a mixture of quite a number of ideas and suggests some of the places where strata formation is a possibility.

3 A detailed study of geological evidence indicates a fairly rapid formation of many rock sequences. This strengthens the case for Creation and weakens the case for Evolution.

I suggest that the devoted band of OU geological students should ask themselves 'How long did it take for this' when considering strata or geological phenomena. If the answer is 'A short time' and repeatedly you find this to be the case, you will be finding, at first hand, evidence for 'Creation'.

Good hunting!

Suggested further reading

What about origins by Dr. A. J. Monty White, published by Dunestone Printers Ltd at £1.80. A scientific presentation of the case for 'Biblical Creation' – takes the literal six day approach.

Is evoloution scientific? by Edgar H. Andrews, published by Evangelical Press. A 21 page leaflet on scientific theory and method.

The Author

John W. Saunderson is a Christian who holds a BA (Open), has passed S234 and intends to pass other OU geology courses in the future. He has worked for a number of years as a coal miner, is a Mining Engineer (C.Eng.) and is a lecturer in mining at a Technical College.

The Ordivician and Silurian Sediments of East Shropshire

The East Shropshire sediments are noteworthy because they represent the shelf facies that accompanied the depositions in the main Welsh syncline of the period. They were formed on the Precambrian/Urconian edge of what is now the Long Mynd.

The Ordivician sediments are best seen to the west of Craven Arms, Salop, on the A489. About a mile and a half west of Craven Arms a low, shallow bank appears on the right-hand (northern) side of the road (GR420857). This is an outcrop of the Upper Caradoc Cheney Longville Flags, a crumbly mixture of fossiliferous sandstones and sandy limestones. The most noteworthy fossil here are the now extinct Tentaculitids, a class of shellfish that became extinct in the Permian. They have conical shells which are like screws except that they have concentric ridges rather than a single spiral one. They are best seen when weathered out, being plentiful in the scree at the foot of the slope. Other fossils here are mainly brachiopods and lamellibranchs, with some trilobite pieces and a few burrows.

A mile further west up the River Onny valley, near a white milestone marked B. Castle 7, C. Arms 2¾ (GR414860) are the Lower Caradoc Chatwall Flags and Sandstones. These are sandstones and siltstones with interbedded shales and the odd bed of sandy limestone. Whilst less fossilferous than the Cheney Longville Flags they do have some noticeable crossbedding, especially about 100 yards east of the milestone (at the end of the fence). 400 yards to the west of the milestone the basal conglomerate of the Caradoc rests on the Urconian. Unfortunately this can only be seen in the river bed.

Another mile or so to the west (GR 394874) the Pentamerus Beds form a small outcrop on a slight slope to the right of the road. These Silurian Llandovery Beds consist of interbedded shales and limestones which are noted for their Pentamerus brachiopods, which weather to show the famous government (prison) arrow from whence the beds get their alternative name, the Government Beds. The basal Kenley Grit conglomerates can be found resting unconformably on the Precambrian basement about ¼ of a mile north of this point (on private land). The beds also contain other brachiopod and mollusc shells.

Only the Upper Llandovery is represented in East Shropshire. During most of the 10 million years that Llandovery rocks were being laid down in Wales the Long Mynd was part of a local high and was being eroded to form the beds to the west. Its partial innudation only occurred right at the end of the period.

To see the later Silurian rocks at their best one has to return to Craven Arms and go up Corve Dale on the B4368 towards Bridgnorth. Near Broadstone (at GR543900) the road cuts through the last of the Silurian beds, the Upper Ludlow Shales (also known as the Whitcliffe Beds). These represent the last of the truly

marine facies as a ¼ of a mile to the east freshwater species dominate the fossil records for this period. Here shallow water brachiopods such as the heavily wrinkled and ribbed Camarotoechia and the less heavily ribbed semi-circular Protochonetes are to be found alongside lamellibranchs and chitonous worm tubes.

By going *back* down the B4368 and taking the first right towards Rushbury you can reach the most interesting site of the area at Upper Millichope (GR520895). Preserved by the Shropshire Conservation Trust to prevent too much further damage, these Lower Ludlow Shales (Elton Beds) are a haven for fossil hunters. The best specimens are to be found in the screes, and the stream banks, except those on the main island access, are protected. Please follow the notices regarding specimens from this locality as it is already suffering from 'geological' erosion. There are ample good specimens of the trilobite Dalmanites in the scree, as well as brachiopods, molluscs, nautiloid cephalopods and some rare graptolites. The trilobite specimen we found, without the aid of a hammer, in the flaggy calcerous shales even contained a fossilised multi-faceted trilobite eye!

A good overall view of the Silurian geology of the area can be had by going on to Rushbury and going up the B4371 to a point ¼ of a mile northwest of the Plough Inn (good food and beer) where an outcrop of Wenlock Limestone opposite the old limestone quarry (GR573967) offers a superb view of the area. The valley immediately in front of the outcrop is in the Wenlock Shales, which join the Upper Llandovery Hughley Shales just before the village of Hughley down in the valley. The hills beyond are the Ordivician Caradoc series again. To the north you can see the Wrekin and to the southwest Caer Caradoc, both Urconian. Looking in the other direction, the first ridge is of the Silurian Ammestry Limestone, the second of the Devonian Old Red Sandstone and beyond that the Carboniferous Brown Clee Hill can be seen. After such a breathtaking view you need a rest at the Plough!

Note: My thanks to Dr. Alan Thomas of Aston University for introducing me to these sites on one of the OUGS field trips.

Note to Branch Organisers

Copy for the next Journal must be with me no later than September 8th. This will be for the last Journal this year, so please make the most of this last chance to tell absent members what you have been doing for them (before they have to vote for you at your next AGM!).

Anyone know a printer?

OUSA are now charging us almost £200 for printing the 700 Journals each issue, including the cost of envelopes and labelling ready for posting. Can anyone suggest a cheaper source of printing? If so please contact me.

Martin Bryan

The development of the Ice Age concept

F. W. Shotton

The thought that Britain might have been invaded by glaciers and much of it covered by great sheets of ice would not have crossed the minds of men, even in a simple form, before the end of the eighteenth century. A great erratic block out of context with its surroundings could either be explained as a missile thrown by one giant against a rival, or even tossed by the Devil himself, or simply accepted as a quirk of the Creator when he fashioned the Earth. Literal interpretation of the Bible was the order of the day, and as late as 1823 William Buckland, the first Professor of Geology at the University of Oxford and a Dean of the church, published his famous *Reliquiae Diluvianae*, in which he presented evidence to prove the existence of the Noachian Deluge. Buckland magnificently documented the occurrence of animal bones, including the 'Red Lady of Paviland', in British and foreign caves, and even in certain gravels which we now know to be Pleistocene; but these animals included certain very non-British species such as elephant, rhinoceros, hyaena, bear and hippopotamus. What could be simpler, therefore, than to exterminate these animals by the Great Deluge? Thus arose Buckland's threefold classification of geologically recent deposits into *antediluvial, diluvial* and *post-diluvial* (or *alluvial* as he preferred). Gravels on the high land of the Cotswolds, now interpreted as fluvioglacial deposits of various Pleistocene ages, were seen as being due to the advancing waters of the Flood, which on their retreat incised the modern valleys. Quod erat demonstrandum!

It is to the credit of Buckland that 15 years later he was a firm proponent of glaciation. However, as much as 40, or more, years earlier ice had been suggested as an explanation of the existence of erratics, as Saussure had named them in 1779. Whalers had brought back tales of icebergs in polar seas carrying large blocks of rock, which eventually fell into the sea. No other explanation seemed needed for the erratics found on land; but the heights at which they occurred called for a great rise of sea-level and substantial drowning of the continents. It was the postulated drifting of the icebergs which gave rise to the term 'glacial drifts' which persists illogically to this day.

This hypothesis of iceberg drift was long in dying. As late as 1857 Hull, in a publication of the Geological Survey, demonstrated to his own satisfaction that Pleistocene gravels against the Cotswold scarp belonged to a beach about 700 feet above sea level. The last advocates of marine submergence and berg transport wrote as late as 1899 in the USA and 1905 in Britain.

But our own James Hutton had, in 1795, invoked an extension of the Alpine glaciers to explain erratics in the Jura, and this was apparently the first recognition

of the action, beyond its present day limits, of land ice. For the next 30 years little progress was made against the prevailing theory of iceberg drift and marine submergence. Then, between 1821 and 1840, a revolution in thought was brought about by European geologists and engineers. Venetz (Swiss), Esmark (Norwegian), Bernhardi (German), De Charpentier (Swiss), Agassiz (Swiss) and even Buckland successively produced incontrovertible evidence not only that the Alpine glaciers had advanced far to the north but, more significantly, that a continental ice sheet had grown from the north to cover much of Europe and even parts of Asia. Similar ideas were permeating North America. The Ice Age concept had taken shape, and more and more attention began to be given to fixing the limits of these ice sheets.

The early workers probably only thought in terms of one great refrigeration, but from the middle of the nineteenth century the surveying geologist made his great contribution. Boulder clay (as till was usually described) was interpreted as the ground moraine of glaciers so that, when two sheets of boulder clay were mapped as separated by sand or gravel which was obviously water-deposited, this situation was naturally interpreted as two ice advances separated by a retreat. Thus was born the concept of 'glacials' separated by 'interglacials'. We now know that water-lain sediments can be deposited within a glacier; so geologists were not (and still are not) always right in ascribing different ages to two separated tills. But equally they are not always wrong. So the concept of 'multiglaciation' was born. The elaboration, refinement and chronology of what is now recognised as a very complex history were to dominate research over the next century to the present day.

In this connection possibly the most significant contribution of the nineteenth century was made by Penck in 1882, and later with Bruckner in 1895. They studied the flights of terraces that characterise the alpine rivers that flow northward into Germany and Austria. They described, on the highest terrace, terminal moraines with outwash gravels beyond, situated far in advance of the modern position of glacier fronts in these same valleys. On the terrace below they demonstrated the even greater extent of an old glacier, with oscillations in its frontal position. An equally great extension, again with oscillations, was demonstrated on the third terrace, and on the lowest terrace more frontal positions of ancient ice, though this time not as far in advance of the modern glacier front as on the previous two terraces.

Thus arose the first serious classification of a sequence of glacial and interglacial stages. The glacial stages were named after the rivers where the respective terraces were well developed – in order of age, with the eldest first, the Günz, Mindel, Riss and Würm terraces. Between these periods the downcutting activity of the rivers, extending far back into the Alps, betokened ameliorations of climate. Penck and Bruckner's basic classification scheme is still extensively used in Southern Europe, even though it has been much amplified and greatly extended back in time.

With the recognition that the 'Ice Age' was a series of climatic oscillations and not just an isolated catastrophe, work during the last hundred years has turned more and more to the evaluation of these cycles. The determination of climatic and ecological parameters depends upon the evaluation of biological or physical criteria. In the first class lie the use of plant fossils, especially pollen (first used in 1876) and the use of animal fossils – not only vetebrates but also foraminifera, ostracods, molluscs, crustacea and insects. Physical criteria include the tracing of erratic trains, the fabrics of tills which depend on a glacier's mechanics, and extra-glacial effects such as cryoturbation (frost disturbance), ice-wedge casts, wind sculpturing and fossil soils. Most striking of all recent developments has been the evaluation of the ratios of oxygen-16 to oxygen-18 in foraminifera of the deep ocean oozes. Successive layers build up a complex picture of numerous cycles of temperature variation in oceanic waters as ice sheets waxed and waned on the continents.

Putting the complex succession of warmer and colder periods into relative order has for long been an accepted task of the stratigrapher. If unquestioned correlation of these events throughout the world is to be achieved, exact dates need to be determined. This is one of the great challenges of the Ice Ages. Dating by radiocarbon and potassium-argon change are accepted methods, but they have severe limitations imposed by the short time span covered by the first method and the difficulty in finding rocks suitable for dating by the second. Progress is being made in the testing of other methods, including radioactive uranium-thorium ratios, isomerism of amino-acids and thermoluminescence. Much work is also being done on an indirect method of dating and correlation, by determining the remanent magnetism of deposits and fitting this into the sequence of normal and reversed fields which has been worked out and dated elsewhere, mainly by the potassium-argon technique. Although the concept of the Ice Age was established a century and a half ago its elaboration since then has progressed with an increasing momentum, which has never been so great as it is today.

The Author

Professor Shotton is Professor Emeritus at the University of Birmingham, and this essay is based on a lecture given on October 4th 1979 under the auspices of the Geological Museum and the Department of Extra Mural Studies at the University of London.

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Sponsorship

Can anyone suggest firms or organisations that might be willing to sponsor production of the Newsletter and/or Journal, or who might provide help with the printing? Free advertisements, etc., can be offered in return. Any possible contact names should be sent to me in Churchdown.

Martin Bryan

Branch Reports

Visit to the Dorset Coast

Several members of the Walton Hall branch of the OUGS joined the Wessex branch on a field trip to the Dorset coast, staying for the weekend in order to see as much of the scenery as possible. The weather was very cold and windy, but the sun shone at times on Sunday and some of us managed to get sunburnt! Mike Henty even managed a paddle in the sea early on Sunday morning. Perhaps the temperature of the hotel drove him to do it – the hotel had no central heating – all the parts were there but had not been connected together!

However, I'm sure we all learned a lot about the geology of the area and we all managed to add to our fossil collections. As most of us seemed to be studying S337 this year this field trip was a relevant one in that it related to the Jurassic case study.

Our first visit was to Eypesmouth, where the tide was just starting to go out. We walked along the beach towards Thorncombe Beacon, where the Middle and Upper Lias can be seen (see Figure 1). At the top of the Middle Lias is a highly fossiliferous band of limestone called the Junction Bed. This is crowded with ammonites, and large blocks could be seen lying on the beach. Beneath the Junction Bed are the Laminated Beds and the Micaseous Beds, topped by the Thorncombe Sands. Some of us were lucky enough to find some excellent fossil specimens.

Returning to Eypesmouth we then walked in the opposite direction towards Bridport. At the beginning of Watton Cliff a fault can be seen which downthrows the Great Oolite Series against the Middle Lias. The whole of this area is subject to rock falls and slides, but the faulted area can be clearly seen. The Fuller's Earth, Beuti Bed and Forest Marble of the Great Oolite Series were also inspected, despite the threat of sliding mud. As it was very cold we adjourned to the hotel and spent an interesting evening enjoying the hospitality of Lyme Regis.

The following day we assembled at Charmouth (see Figure 2). We started by looking at Black Ven, where the Shales with Beef caused great amusement. These get their name from the presence of numerous interbedded seams of fiborous calcite, which give a superficial resemblence to beef. Returning to Charmouth we collected our lunches and set off towards Golden Gap. This proved to be one of the most interesting parts of the weekend. As the tide receded many small pyritised ammonites were found, but also revealed were recent sedimentary structures formed by mud flows caused by cliff erosion. Here was geology in action! Also seen on the beach was a large half-embedded piece of limestone showing well preserved ripple marks, the crests of which were encrusted with pyrites and ammonites.

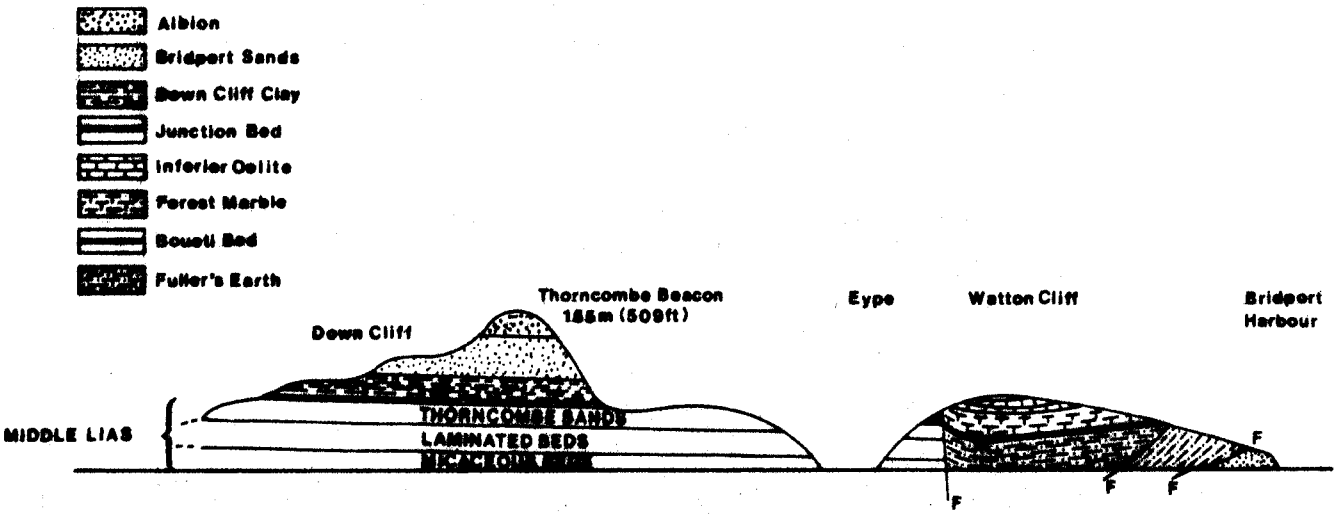


Figure 1

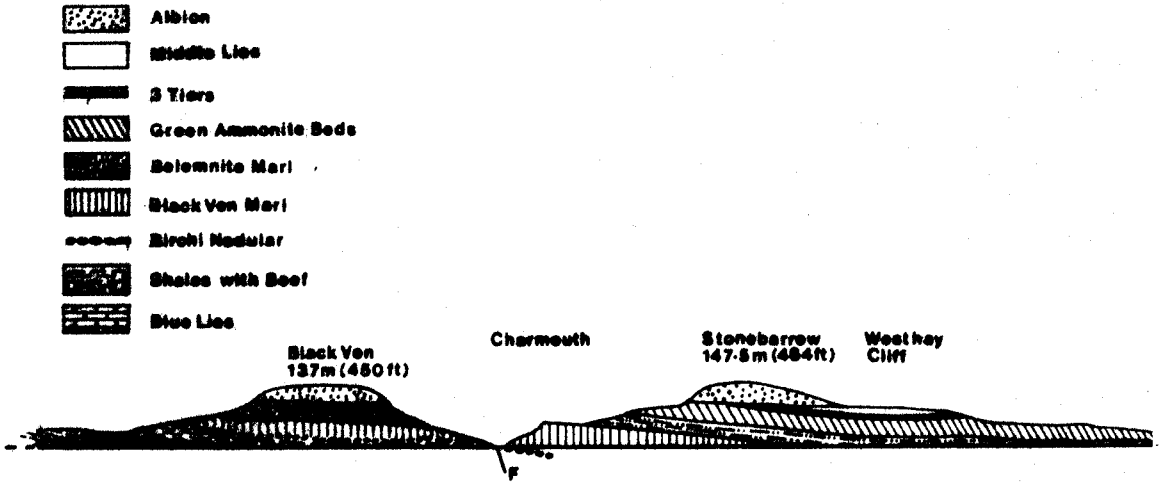
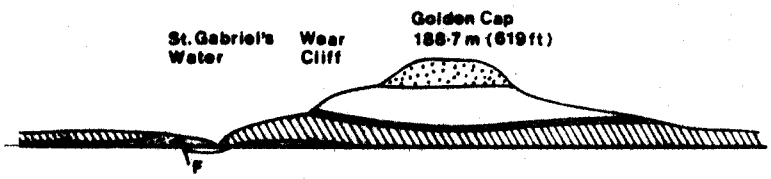


Figure 2



Some of the more energetic members walked as far as Golden Gap and returned to find no food left and nowhere to go but home! Having left home at 5.30am on the Saturday morning we returned home tired but happy at 11pm on Sunday.

Up Mountains, Down Mines

Over the Spring Bank Holiday twenty OUGS members took part in a three day field trip arranged by the Wessex Branch. It was based at Dolgellau Youth Hostel under the leadership of its warden, Graham Hall.

After an introductory discussion on Friday evening, the first day's excursion was to the northwest of the Lleyn peninsula to examine Precambrian rocks of the Mona complex. Assembling at Nefyn, the group examined exposures of amphibolite gneiss in contact with greenschists on the wave-cut platform to the north of the bay. Some discussion ensued as to whether the junction was gradational, as proposed by Shakelton (1956), or faulted.

Returning to the vehicles, we proceeded southwestwards along the coast, making a series of stops to examine coastal exposures of the sedimentary and volcanic rocks of the Mona complex. At Porth Colman enormous boulders of quartzite were seen within a sequence of marine shales: this formed an example of the remarkable Gwna melange, a subaqueous slide breccia. A little further along the beach platform a sequence of greywacke turbidites outcropped. These beds have a near-vertical dip, and their way-up was deduced from graded bedding and other sedimentary structures.

At Porth Oer, after making use of the fortuitously situated beach cafe, an impressive outcrop of basalt pillow lavas was examined at the north end of the beach. Associated with the lavas are jasper and limestone. We then crossed the sands southwards to the wave-cut platform where basic ashes of the Gwna Group display numerous minor folds with well developed axial-planar cleavage.

At Mynydd Gwyddel a short stop was made to examine the acid pyroclastics of the Gwyddel Group, and to admire the impressive cliff scenery and view of Bardsey Island. The party then proceeded to Parwyd, where a somewhat hazardous descent of the clifftop allowed a glimpse of the Ordivician Arenig basal sandstone lying unconformably on eroded Mona gneiss. Those members of the group with a strong head for heights continued the descent to sea level to examine the Arenig beds in greater detail. Coarse conglomerate horizons were found to contain a variety of clasts, including Mona schists and gneiss.

During the return journey a roadside quarry near Sarn was visited to collect specimens of the Precambrian Sarn granite (which isn't a true granite! - Ed).

Sunday started with a traverse of Cader Idris, during which a variety of Ordivician volcanic and intrusive rocks were seen. At the first stop, at Bwlch Llyn Bach, the line of the Tal y Llyn fault was pointed out. There was some discussion of the importance of this major fracture in controlling sedimentation and volcanicity during the Lower Paleozoic era. Leaving the vehicles at Minffordd, the group

began the arduous ascent through the oakwoods to the Cwm Cau cirque basin. From this vantage point could be seen many impressive geomorphological features resulting from glacial and periglacial processes. Continuing the ascent to the Craig Lwyd ridge the ash flow tuffs of the Upper Acid Group were examined. The granophyre boss of Mynydd Moel could be identified in the cliffs overlooking the cirque basin to the northeast: this intrusive was thought by Davies (1959) to represent the volcanic vent through which some pyroclastics of the Upper Acid Group were erupted.

In the saddle below Pen y Gadair the Upper Acid Group was seen to be underlain by the marine Llyn Cau Mudstones, which in turn were underlain by the Upper Basic Volcanic Group as the summit of the mountain was approached. Within the Upper Basic Group appear vesicular basalts, rubbly basalts and pillow lavas. These volcanics show a marked alteration to spilites, and it was mentioned that dolerite sills emplaced at shallow depth during the same phase of vulcanicity show similar alteration: this is taken to indicate intrusion into unconsolidated marine muds with a saline water content (Ridgeway, 1971).

From the summit we made our way to the head of the much threatened Fox's Path, which descends as a scree slope for 700 feet into the Llyn y Gadair cirque basin. The back wall of the cirque, and indeed the major part of the north-facing scarp of the mountain, is composed of a massive granophyre sill which represents a high level magma chamber associated with the eruption of the Upper Acid Volcanic Group. A return was made on foot to the Youth Hostel via the Gwernan Lake.

After the evening meal, much to most people's surprise, the group was reconvened to make an underground exploration of the disused Friog slate mine near Fairbourne. After climbing the path between tips of slate waste, the entrance to a series of chambers was located where the Upper Cambrian Tremadoc Slates had been worked. Members were much impressed by the enormity of the excavations, which could have accomodated a moderate sized tower block.

On Monday morning we made our way into the Coed y Brenin Forest to visit the disused Gwynfynydd Gold Mine, where quartz-sulphide mineral veins of Caledonian age occur in Upper Cambrian sediments. The group first viewed the picturesque waterfalls near the confluence of the Rivers Mawddach and Cain. The Pistyll Cain falls were seen to occur where the massive Cefn Coch Grit crosses the river within a sequence of somewhat less resistant shales, and the Rhaeadr Mawddach falls were seen to be formed by a thick dolerite sill within the shale sequence.

Following the River Mawddach upstream, the entrance to the number 6 level of the Gwynfynydd Mine was reached. Thanks to the availability of local leadership to guide us through this complex and potentially dangerous old mine we were able to climb safely through it. After a short distance the adit emerged into a large chamber containing the headframe for winding skips of ore from lower levels now flooded. The group was able to examine ore workings, known as stopes,

before ascending a series of ladderways to finally emerge from the number 2 level some 300 feet higher up the valley side.

The gold mineralisation was explained as being associated with faulting during the uplift of the Harlech Dome during the Caledonian earth movements. Quartz lodes usually occur adjacent to dolerite intrusions, which developed marginal shear zones due to their contrast in competence with the shale country rock. The quartz lodes have an extensive distribution through the Upper Cambrian strata, but important deposits of gold are confined almost exclusively to the Clogau Shale formation. The Clogau Shales contain pyrite formed during deposition in a marine environment, and it is thought that the presence of pyrite initiated precipitation of gold from a chloride complex in the hydrothermal mineralising solution (Gilbey,1968).

A search of the tips outside the number 2 level produced some excellent specimens of galena (several kilograms in weight!), copper pyrite and zinc blende. Some more doubtful microsamples of gold were also forthcoming.

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Shackelton, R. (1956) Notes on the structure and relations of the Precambrian and Ordovician rocks of SW Lleyn, *L'pool Mchr Geol. J.*, 1, 400-409.

Editor's Note

Anybody wishing to follow this fascinating, if fairly exhausting, itinerary is advised to contact Graham Hall at the Kings Youth Hostel near Dollegau. Graham's superb, and challenging, Geological (£1) and Geomorphological (50p) Notes on the area, which are only sold at the hostel, formed the basis of this excellent trip, and hopefully will form a future paper on the area in the Journal. Any teachers wishing to run trips to this area should note that the hostel is run as a geological/geographical field centre, and has all the necessary facilities for a full study of the area.

West Midlands

Since our initial field trip to the Wrekin we have almost become an established, if young, branch. We have (at the time of writing) acheived two things; a respectable membership and, thanks to Isla, a fairly full year's programme of field trips. So far, in addition to the Wrekin trip reported in the last Journal, we have had a field trip and a mine visit, all very well supported.

The mine visit took us to Hem Heath Colliery, Stoke-on-Trent, on Sunday 23rd March. We had 12 members on this visit (the maximum allowed by the Coal Board), with a list of a further 10 names of people hoping for a drop-out. Our descent into the mine took us to a middle level, and we walked along this to the coal face. The face was about 200 yards long, with a roadway at both ends. We approached the face along one roadway and returned along the other, having viewed the length of the face. The two most notable features were the dirt and the cheerfulness of all the miners (apart from the geological features, of course). We were down the mine for about 3½ hours, and on our surfacing I think everybody had a better appreciation of what mining is like. A trip well appreciated by all concerned.

Our next trip was to South Shropshire to look at the Ordovician and Silurian sediments. This trip took place on Sunday 24th April and was led by Dr. Alan Thomas of Aston University. Three sites in the Wenlock Edge area were visited to see the Silurian sediments and three on the Onny valley to study the Ordivician. This was a paleontological trip and consequently many fossils were studied, and some collected, although I hasten to add that these came from loose rock fragments. The sites visited, in order, were: the Lower Ludlow Shales at Upper Millichope in Hope Dale; the Upper Ludlow Shales in Corvedale; the Wenlock Edge viewpoint near the Plough Inn (where an enjoyable lunch was taken); the Odivician Government Beds of the Onny valley; the Ordivician Chatwell Flags and the Cheney Longville Flags further down the valley.

All in all this was a very enjoyable field trip for the 20 attendees, and Dr. Thomas must be commended for the way he led the trip; all questions were fully answered and a lot of detail was gone into. A more detailed account of the trip, written in the form of a do-it-yourself field guide, is given elsewhere in this issue.

Yorkshire lose Chairperson

Our first field trip for this year was well supported by friends old and new, and Norma who arrived after we had gone on our merry way. And who was it who didn't leave directions for latecomers?

We enjoyed the usual branch weather, sunshine all the way, taking note of the primroses and wood anemones which gave additional pleasure to our walk along the old single railway track now metalled for road use. Geologically speaking we noted the general trend of the strata and made a closer inspection of one series which revealed a band of fossil-bearing chert (crinoidal), discussing its merits as a marker band in some depth.

The folding at Ecton Hill is complex and as far as we know it has not been documented. It appeared at one point that a recumbent fold had sheared across the top of a series of beds which dipped at some 70 degrees as they were themselves part of an anticline.

After lunch we climbed to the top of the hill, where spoil heaps yielded specimens of copper minerals, chalcopyrite, azurite and possibly malachite, even though a 10x lens was needed to appreciate them. Interesting platy calcite crystals, barite and flourite specimens were also found. On our return to Wetton Mill we found Norma, still amicably disposed despite my omission, and so ended a good day's outing.

The Ludlow weekend is already heavily subscribed, though I will add your name to the standby list if you like.

John Davenport

OU Projects

The Meldon Reservoir paper in this issue was written as an S333 project. There must be many such potential Journal items among members' work which could be reworked without much difficulty from TMAs, or be submitted as is. Why not look at your work and see if it could go in the Journal. I can even arrange to copy your original if that is the problem. Just send it to me by registered mail and your original will be back within a week.

More Deviltry

Collapsed Structure Student after exams

Slump Caused by viewing exam papers

Divergence Two geologists' views on a given structure

Convergence Students' apparent agreement with course team *thinking* at exam time (mythical)

Creep Features seen moving fixed structures (tutors?) at summer school

Diapir Messy structure known for its intrusions

Dry Valley Place to be avoided on field trips. Particularly noted in Wales!

Come on the rest of you, I can't keep this up for ever!